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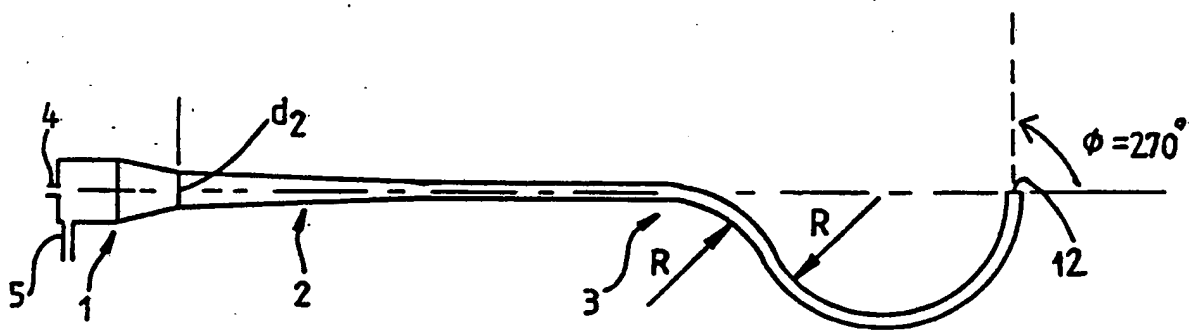

(57) Abstract

A cyclone separator having a separating chamber formed with a primary portion (1) having a side inlet (5) and an axial end outlet (48), a secondary portion (2) and a tertiary portion (3), which portion (3) is curved over part of its length, and wherein $10 \leq 2R/d_2 \leq 30$ where (R) is the radius of curvature of the curved portion and (d_2) is the diameter of the separating chamber at the downstream end of the primary portion (1).

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"CYCLONE SEPARATOR WITH CURVED DOWNSTREAM PORTION"

This invention relates to a cyclone separator with curved downstream portion.

More particularly, the invention concerns cyclone separators for separating multi-phase mixtures such as, for example, oil/water mixtures. Separators of the present invention may find application in separating a lighter phase of a mixture from a denser phase of a mixture such as oil from water. Such separators are often referred to as "de-oilers". There are also cyclone separators which are used for removing substantial quantities of the lighter phase from the denser phase and these are often referred to as "de-waterers".

Cyclone separators of this type generally comprise an elongated separating chamber having a feed inlet proximate to one end and outlets for the lighter and denser phases. Preferably these outlets are generally in the form of an overflow outlet at the same end of the separating chamber as the feed inlet and an underflow outlet at the other end. The overflow outlet is normally adapted for removing the less dense phase and the underflow outlet for removing the more dense phase.

Cyclone separators of this general type have been well documented in patent specifications such as, for example, U.S. patents 4,464,264, 4,544,486, 4,237,006 as well as for example in International application PCT/AU85/00181. By reference to these patent specifications the contents thereof are to be considered incorporated into the present specification.

One of the problems of cyclone separators of this type is that they are generally relatively long devices which means they take up considerable space and are difficult to transport.

It is an object of the present invention to provide an improved cyclone separator which at least to some extent alleviates the aforementioned problem.

Basically the cyclone separator of the present invention comprises elements designed, sized and arranged for treating a mixture of fluids for separating at least in part a more dense component of

the mixture from a less dense component thereof, the cyclone separator comprising a separating chamber having first and second ends, inlet means at the first end for introducing feed to be separated into the cyclone separator and at least two outlets, including an underflow outlet at said second end for outflow of the more dense component of the mixture, said separating chamber including a curved portion extending to said underflow outlet whereby the denser component in use passing to the underflow outlet has its path of movement deflected, from the upstream end of the curved portion to the underflow outlet, by a substantial angular displacement. By this means, the effective length of the separator is reduced. The cyclone separator may include a primary portion at the first end, a secondary portion which is co-axial with and adjacent the primary portion and a tertiary portion at the end of the secondary portion remote from the primary portion and co-axial with the secondary portion, at least where it joins the secondary portion. In this case, the cyclone separator of the present invention is characterised in that the tertiary portion at least is in part curved, and defines said curved portion.

Preferably, in the curved portion, the following relationship applies: $2R/d_2$ is within the range 10 to 30 and more preferably 18 to 28 where R is the radius of curvature of the curved tertiary portion and d_2 is the nominal diameter of the cyclone separator i.e., the diameter at the downstream end of the primary portion.

The invention is further described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a schematic side elevation of a typical cyclone separator which is of the general type to which the present invention relates except that the tertiary portion is not curved.

Figure 2 is a cross-sectional view of the cyclone separator of Figure 1 taken along the axis of the inlet; and

Figures 3, 4, 5, 6 and 7 are various configurations of cyclone separator according to the invention.

Referring to the drawings, Figure 1 illustrates a typical exemplary of cyclone separator which is modified in accordance with the present invention. As shown, the cyclone separator comprises a primary portion 1 which includes a generally cylindrical section 6 and a tapered section 7, with a side inlet duct 5 for delivering the mixture to the separating chamber with a tangential flow component. The separator further includes a secondary or separating portion 2 which is tapered and a tertiary or downstream portion 3 at the end of the secondary portion remote from the primary portion, this being cylindrical. The end of the tertiary portion 3 defines an underflow outlet 12. An axial overflow outlet 48 is also provided, positioned either in the end wall of the primary portion or, as shown, at the

inner end of an axial vortex finder 4. The nominal diameter of the cyclone separator is defined by diameter d_2 and the following geometrical relationships may, for example, apply;

$$\ell_1 = 2d_2$$
$$d_1 = 2d_2$$
$$d_3 = d_2/2$$
$$\theta = 10°$$
$$\alpha = .75°,$$

these variables being as designated in Figure 1.

Preferably, the inlet duct 5 feeds into a spiral feed channel 8 which in one form may be involute. Although the separating chamber shown has side wall portions which are linear, this is not essential. However, more generally, cyclone separators to which the invention is best applicable may be characterised as comprising:

(a) an inlet portion having generally the form of a volume of revolution, and one or more inlet channels,

(b) an overflow outlet coaxial with the inlet portion,

(c) a generally axially symmetrical converging separation portion adjacent to the inlet portion and on the opposite side from the vortex finder outlet, and, optionally,

(d) a downstream portion into which the separation portion converges, and, optionally,

(e) a vortex finder in the form of an axial tube projecting through the end wall of the separating chamber at the inlet end into the inlet portion and in this case defining at its inner end the overflow outlet.

The following relationships (i)-(v) applying wherein d_o is the minimum internal diameter of the overflow outlet at the separator end wall if no vortex finder is provided, or where provided, within $3d_2$ of the inlet plane or at the vortex finder end if this is not within $3d_2$ of the inlet plane,
d_1 is the diameter of the cyclone in the inlet portion where the feed enters, neglecting any inlet channel,
d_2 is the diameter of the cyclone where the inlet portion joins the separation portion, the junction being as hereinafter defined,
d_3 is the diameter of the cyclone where the separation portion ends or joins the downstream portion, the junction being as hereinafter defined,
d_{ix} is twice the radius at which flow enters the cyclone through the x^{th} inlet, (i.e., twice the minimum distance of the tangential component of the inlet centre line from the axis),
A_{ix} is the cross-sectional area of the x^{th} inlet, as hereinafter defined,

$$A_i = \sum_{x=1}^{n} A_{ix}$$

$$d_i = \frac{1}{A_i} \sum_{x=1}^{n} d_{ix}A_{ix}, \text{ and}$$

α is the half angle of convergence of the separation portion as hereinafter defined:

(i) $$3 \leq \frac{\pi d_2 d_i}{4A_i} \leq 30, \text{ such as}$$

$$8 \leq \frac{\pi d_2 d_i}{4A_i} \leq 16$$

(ii) for dewatering geometries:

$1° \leq \alpha < 3°$, suitably $1\ 1/2° \leq \alpha < 3°$, conveniently $2° \leq \alpha < 3°$;

or for deoiling geometries:

$20' \leq \alpha \leq 2°$, such as $52' \leq \alpha \leq 1°$.

(iii) for dewatering geometries:

$$0.25 < \frac{d_o}{d_2} < 0.65;$$

or, for deoiling geometries:

$$\frac{d_o}{d_2} < 0.2$$

(iv) $0.9\ d_1 > d_2$

(v) $0.9\ d_2 > d_3$

The inlet plane is defined as the plane perpendicular to the axis of the cyclone at the mean axial position of the weighted areas of the inlets such that the injection of angular momentum into the hydrocyclone is equally distributed axially about it and is thus such that

$$\frac{1}{A_i d_i} \sum_{x=1}^{n} Z_x A_{ix} d_{ix} = 0,$$

wherein Z_x is the axial position of the centre line of the x^{th} inlet. The inlet plane is designated by reference numeral 8 in Figure 1.

The junction of the inlet portion and the separation portion is defined as being at the axial position z_2 (measured away from the inlet plane where z=0) where the condition first applies that:

$$\tan^{-1}\left(\frac{d_2-d}{2(z-z_2)}\right) < 3°,$$

for a dewatering cyclone, or

$$\tan^{-1}\left(\frac{d_2-d}{2(z-z_2)}\right), 2°,$$

for a deoiling cyclone, for all $z \geq z_2$, where d is the cyclone diameter at z.

The junction of the separation portion and the downstream outlet portion, if present, is defined as the diameter at z_3 where $d/d_3 \geq 0.98$ for all $z \geq z_3$.

a is defined as

$$\tan^{-1}\left(\frac{d_2-d_3}{2(z_3-z_2)}\right)$$

A_{ix} is the minimum cross section of the inlet at entry to the cyclone in a plane parallel to the axis of the cyclone.

Where the overflow outlet is provided in a vortex finder, the so provided vortex finder outlet preferably terminates within $3d_2$ of the inlet plane, this distance being defined as l_o.

Preferably the axial overflow outlet, i.e., the vortex finder outlet, projects into the cyclone at least as far as the inlet plane.

The expression

$$\frac{\pi d_2 d_i}{4A_i},$$

termed the "swirl coefficient" and designated S, is a reasonable predictor of the ratio of velocities tangentially: axially of flow which has entered the cyclone and which has reached the plane of d_2.

The or each inlet channel is preferably fed from a duct directed substantailly tangentially into the inlet portion. Each inlet channel may spiral inwardly in a volute entry. The outer surface of the channel may converge to the diameter of the inlet portion d_1 after $\frac{360°}{n}$ around the axis, wherein n is the number of feed channels.

The inlet channel(s) need not be in a plane normal to the axis and may be offset in a generally helical form. They may attain the diameter d_1 after more than $\frac{360°}{n}$ around the axis.

If the inlet portion is itself conical, then the diameter will be approximately d_1.

The convergence averaged from the diameter d_1 measured in the inlet plane to the diameter d_2 may have the greatest cone half-angle θ in the cyclone, which may be in the range 5° to 45°.

The dimensions of the inlet portion should be such that the angular momentum of feed entering from the inlets is substantially conserved into the separation portion. The lengths of the portions 1, 2 and 3 are designated l_1, l_2, l_3 respectively in Figure 1.

It is possible for at least part of the generator of the inlet portion or of the separation portion or of both to be curved. The generator may be, for example, (i) a monotonic curve (having no points of inflexion) steepest at the inlet-portion end and tending to a cone-angle of zero at its open end, or (ii) a curve with one or more points of inflexion but overall converging towards the downstream outlet portion, preferably never diverging towards the downstream outlet portion.

As shown in Figures 3, 4 and 5 the tertiary portion 3, is in accordance with this invention is curved. In Figure 3 the tertiary portion 3 comprises a straight section of length l_3 equal to $20d_2$ plus a curved section having two parts each having a radius of curvature R.

In Figure 4 the tertiary portion 3 comprises a straight section of length l_3 equal to $20d_2$, and a curved portion with a radius of curvature R.

In Figure 5 the tertiary portion 3 comprises a curved portion of radius of curvature R.

In Figure 6 a plurality of relatively reversely oriented curved portions 16, 18, 20, 22, make up an end section 3B of tertiary portion 3, adjacent straight section 3A. Portions 16, 18, 20, 22 are arranged so that such end section 3B is sinuous.

In Figure 7, straight section 3A of the portion 3 cojoins with an end section 3B made up of coiled circular or part circular portions 24, 26.

Generally, it is preferred that each curved portion be part circular or circular, that is exhibit constant curvature such as equal as between portions where there is more than one. This is not essential as the or each curved portion may exhibit varying curvature and/or the curvatures may differ for each. Curved portions may also be interconnected by straight sections.

In each of the separators of each of Figures 3 to 7, it will be noted that the separator is of lesser effective length than would be the case if the portion 3 were colinear with the axis of portions 1 and 2. Generally to achieve significant saving in length there should be at least one curved portion which is effective to deflect the flow therein through at least 45°. Thus Figures 3, 4, and 5 show a deflection angle ϕ of 270°, 180° and 180° respectively. In Figure 6, the combined deflections

are additive and exceed 360° as also is the case in Figure 7.

In any event, as described, it is preferred that the or each curved portion should be characterised by:

$10 \leq 2R/d_2 \leq 30$, more preferably

$18 \leq 2R/d_2 \leq 28$

where R is the radius of curvature of the respective portion and d_2 is as above defined.

Finally, it is to be understood that the inventive concept in any of its aspects can be incorporated in many different constructions so that the generality of the preceding description is not to be superseded by the particularity of the attached drawings. Various alterations, modifications and or additions may be incorporated into the various constructions and arrangements of the parts without departing from the spirit and ambit of the invention, as defined by the appended claims.

CLAIMS

1. A cyclone separator comprising elements designed, sized and arranged for treating a mixture of fluids for separating at least in part a more dense component of the mixture from a less dense component thereof, the cyclone separator comprising a separating chamber having first and second ends, inlet means at the first end for introducing feed to be separated into the cyclone separator and at least two outlets, including an underflow outlet at said second end for outflow of the more dense component of the mixture, said separating chamber including a curved portion extending to said underflow outlet whereby the denser component in use passing to the underflow outlet has its path of movement deflected, from the upstream end of the curved portion to the underflow outlet, by a substantial angular displacement.

2. A cyclone separator as claimed in claim 1 wherein said displacement is at least 45°.

3. A cyclone separator as claimed in claim 1, or claim 2 including a primary portion at the first end, a secondary portion which is co-axial with and adjacent the primary portion and a tertiary portion at the end of the secondary portion remote from the primary portion and co-axial with the secondary portion, at least where it joins the secondary portion. the tertiary portion at least being in part curved, and defines said curved portion.

4. A cyclone separator as claimed in claim 2 wherein said curved portion comprises a section of said tertiary portion which joins a straight section thereof, said straight section joining said secondary portion.

5. A cyclone separator as claimed in claim 1, claim 2 or claim 3 wherein in the curved portion, the following relationship applies: $2R/d_2$ is within the range 10 to 30 where R is the radius of curvature of the curved tertiary portion and d_2 is the diameter of the separating chamber at the downstream end of the primary portion.

6. A cyclone separator as claimed in claim 5 wherein $18 \leq 2R/d_2 \leq 28$.

7. A cyclone separator as claimed in claim 5 or claim 6 wherein d_2 is the diameter of the separating chamber at the axial portion Z_2 (measured away from the inlet plane where Z=0) where the condition first applies that:

$$\tan^{-1}\left(\frac{d_2-d}{2(z-z_2)}\right) < 3°,$$

where d is the cyclone diameter at Z, and wherein said inlet plane is the plane perpendicular to the axis of the cyclone at the mean axial position of the weighted areas of the inlets such that the injection of angular momentum into the hydrocyclone is equally distributed axially about it.

8. A cyclone separator as claimed in claim 5 or claim 6 wherein d_2 is the diameter of the separating chamber at the axial portion Z_2 (measured away from the inlet plane where Z=0) where the condition first applies that:

$$\tan^{-1}\left(\frac{d_2-d}{2(z-z_2)}\right) < 2°,$$

where d is the cyclone diameter at Z, and wherein said inlet plane is the plane perpendicular to the axis of the cyclone at the mean axial position of the weighted areas of the inlets such that the injection of angular momentum into the hydrocyclone is equally distributed axially about it.

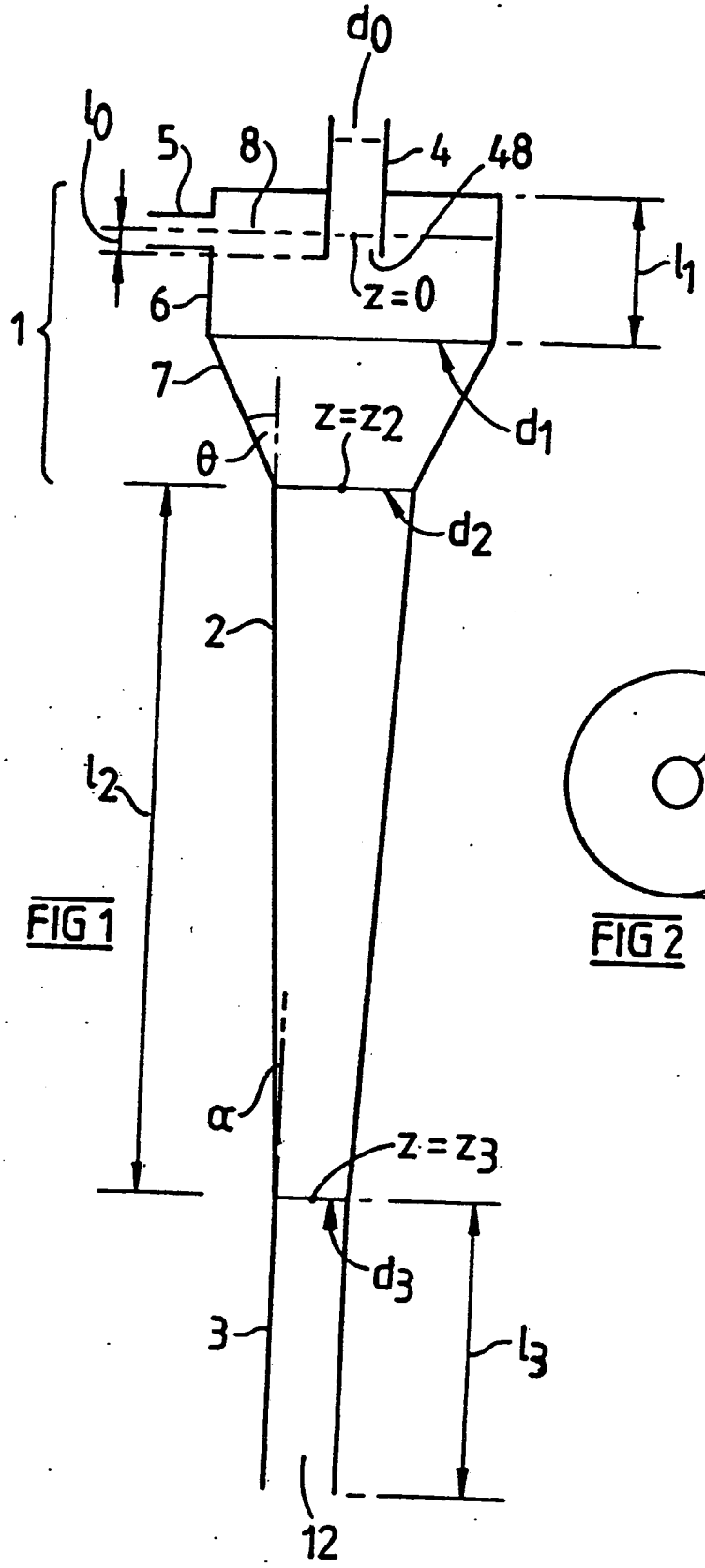

FIG 1

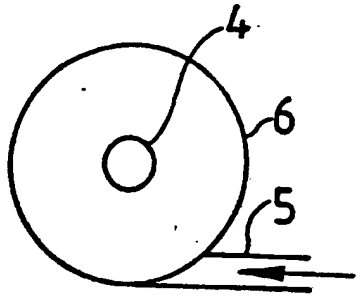

FIG 2

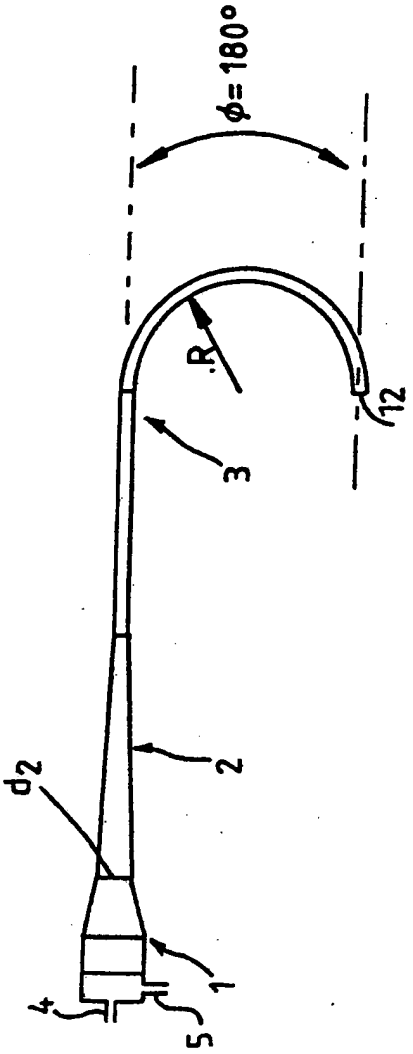

FIG 4

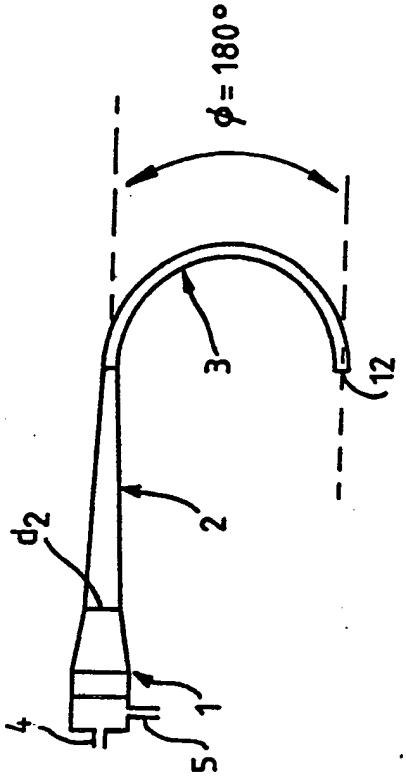

FIG 5

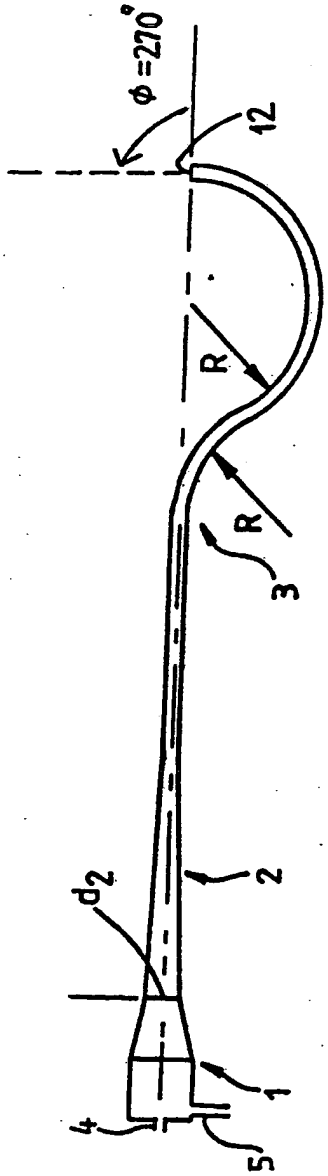

FIG 3

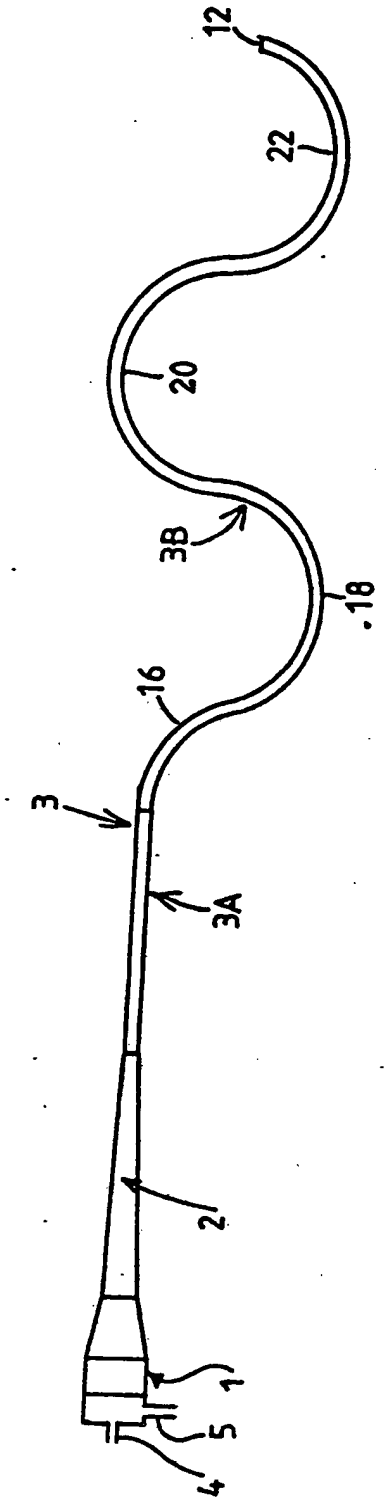

FIG 6

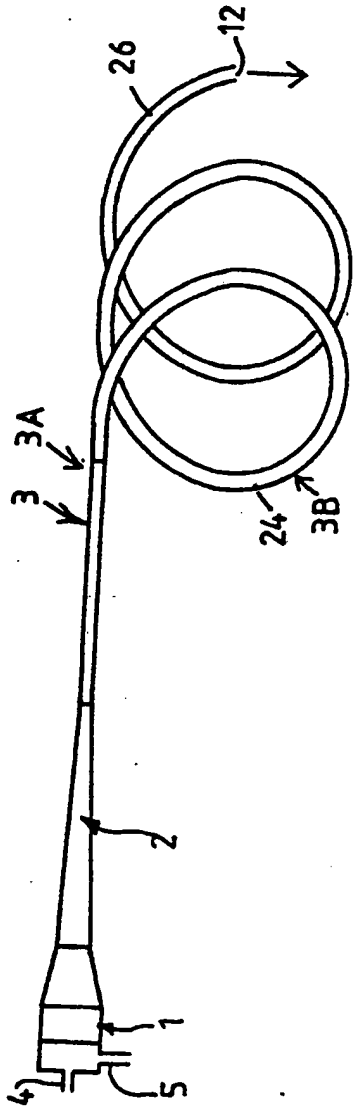

FIG 7

INTERNATIONAL SEARCH REPORT

International Application No PCT/AU 88/00384

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.[4] B04C 5/14

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC	B04C 5/14

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

AU : IPC as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [10]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X	AU,A, 46753/85 (B.W.N. VORTOIL RIGHTS CO. PTY LTD) 27 February 1986 (27.02.86) See page 1 to 3, figure 1	(1-4,8)
X	AU,A, 84713/82 (NATIONAL RESEARCH DEVELOPMENT CORPORATION) 6 January 1983 (06.01.83) See figure 1	(1-4)
X	AU,B, 44438/58 (229644) (IMPERIAL CHEMICAL INDUSTRIES LTD) 25 June 1959 (25.06.59) See figure 1	(1-4)
X	AU,B, 2533/54 (200427) (STAMICARBON N.V.) 24 February 1955 (24.02.55) See figure 3	(1-4)
X	AU,B, 11896/52 (162565) (VICTOR RAKOWSKY) 16 October 1952 (16.10.52) See figure 3	(1-4)
X	US,A, 4251368 (COLMAN et al) 17 February 1981 (17.02.81) See figure 1	(1-4)
X	DE,A, 2051357 (J.M. VOITH GmbH) 31 May 1972 (31.05.72) See figure 1 and 3	(1-4)
A	AU,B, 40105/58 (227296) (VICTOR RAKOWSKY) 5 February 1959 (05.02.59) See figure 4	(1,2)
A	GB,A, 2081691 (SEITZ-WERKE GmbH) 24 February 1982 (24.02.82) See figure 1	(1,2,4)

* Special categories of cited documents: [12]

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
16 January 1989 (16.01.89)	25 JANUARY 1989 (25.01.89)
International Searching Authority	**Signature of Authorized Officer**
Australian Patent Office	J.P. ELIJAH

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ANNEX TO THE INTERNATIONAL SEARCH REPORT ON
INTERNATIONAL APPLICATION NO. PCT/AU 88/00384

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report	Patent Family Members		
GB 2081691	DE 3024099	FR 2485502	US 4390048
US 4251368	AU 47106/79	GB 1583730	
AU 84713/82	CA 1191111	EP 68809	GB 2102310
	JP 58030356	MY 32/86	NO 822136
	US 4576724	US 4722796	
AU 46753/85	BR 8507218	DK 1496/86	EP 216780
	FI 870434	GB 2162445	GB 2187401
	NL 8520221	NO 861202	US 4764287
	WO 8601130		

END OF ANNEX